



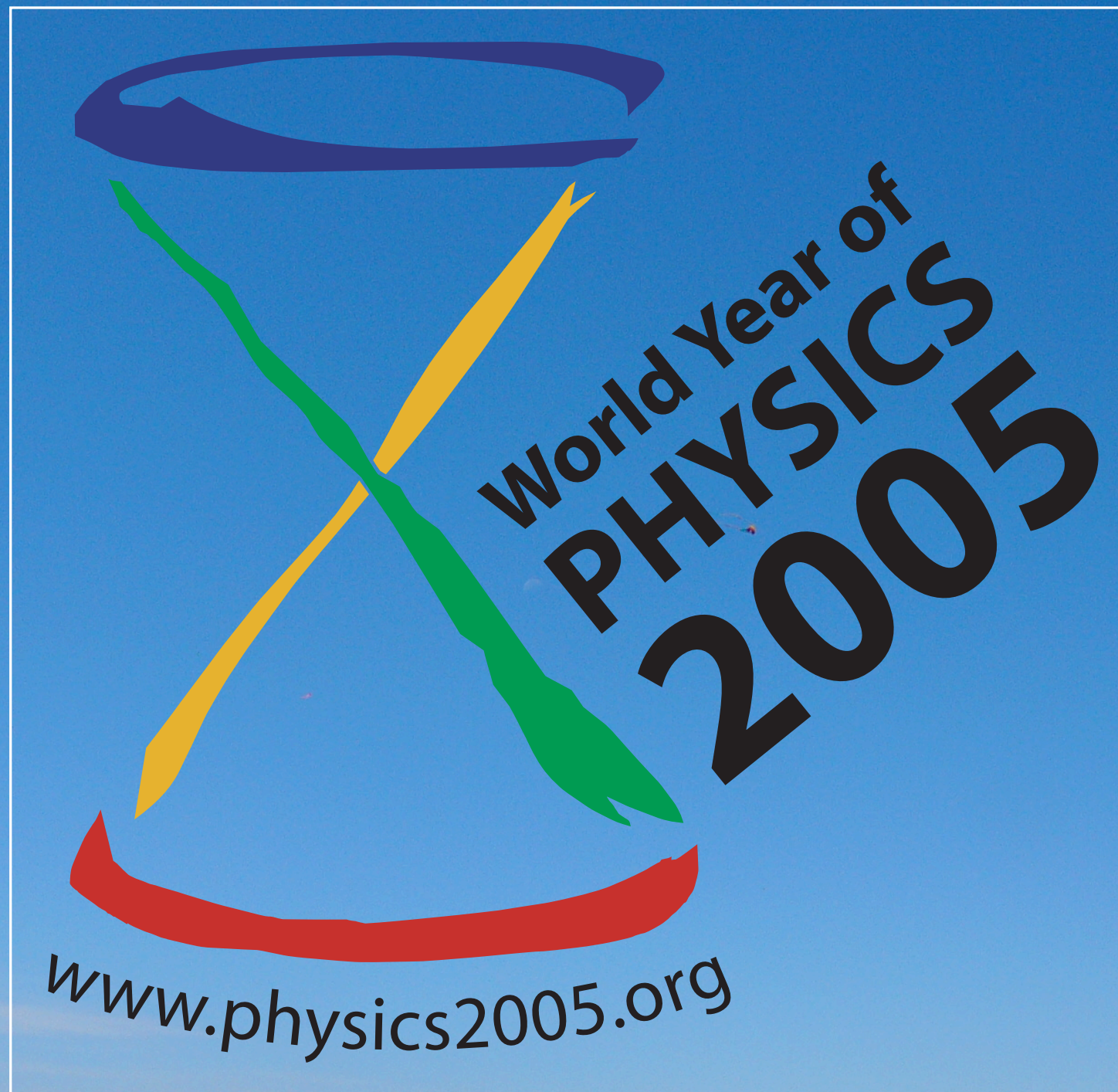
Physical Reflections on World Year of Physics, Near-Perfect Fluids, & Quantum Diaries

Peter Steinberg, Chemistry Department

BROOKHAVEN
NATIONAL LABORATORY

Brookhaven Executive Roundtable June 8, 2005





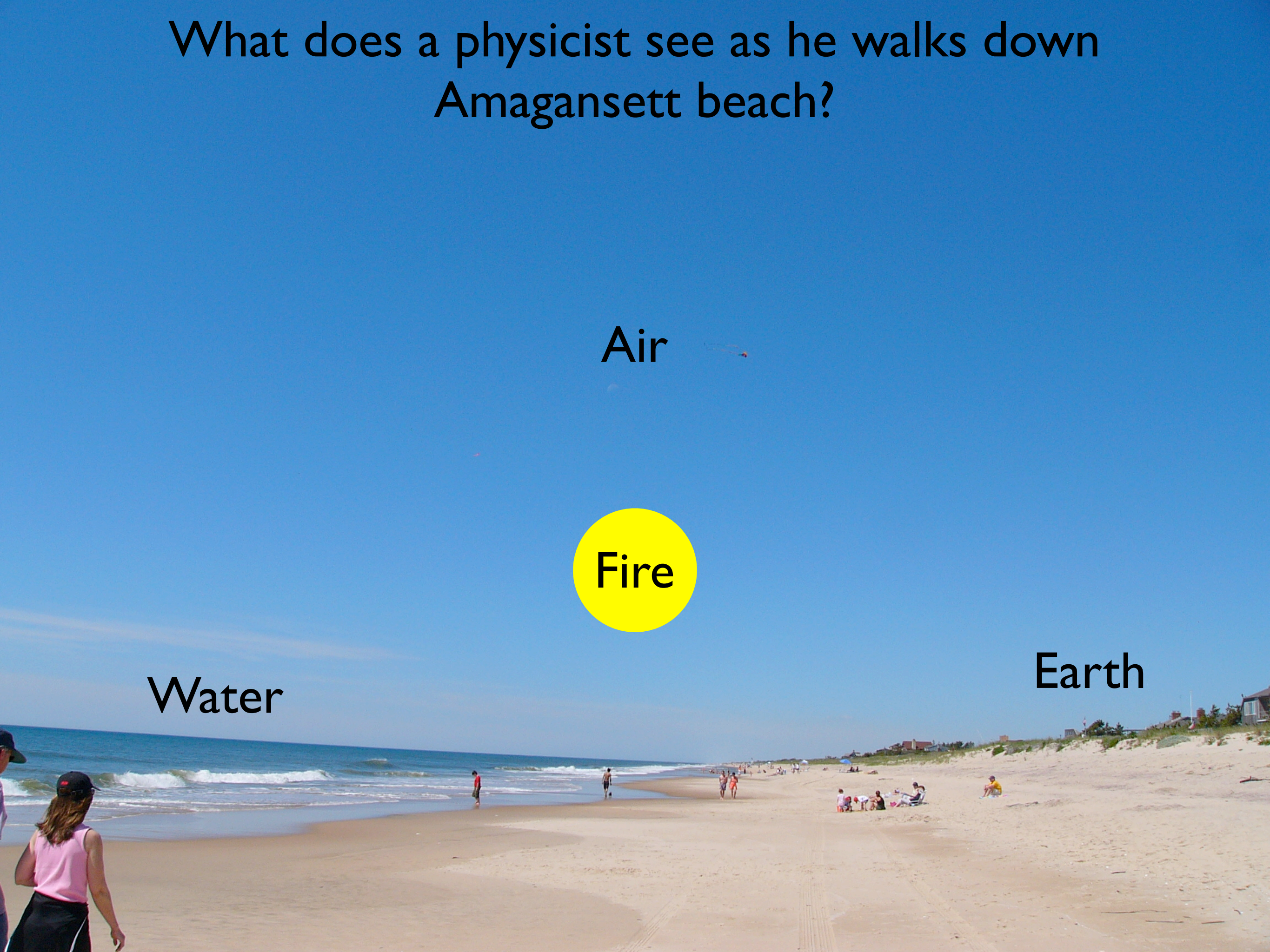
What does a physicist see as he walks down
Amagansett beach?

Air

Fire

Water

Earth



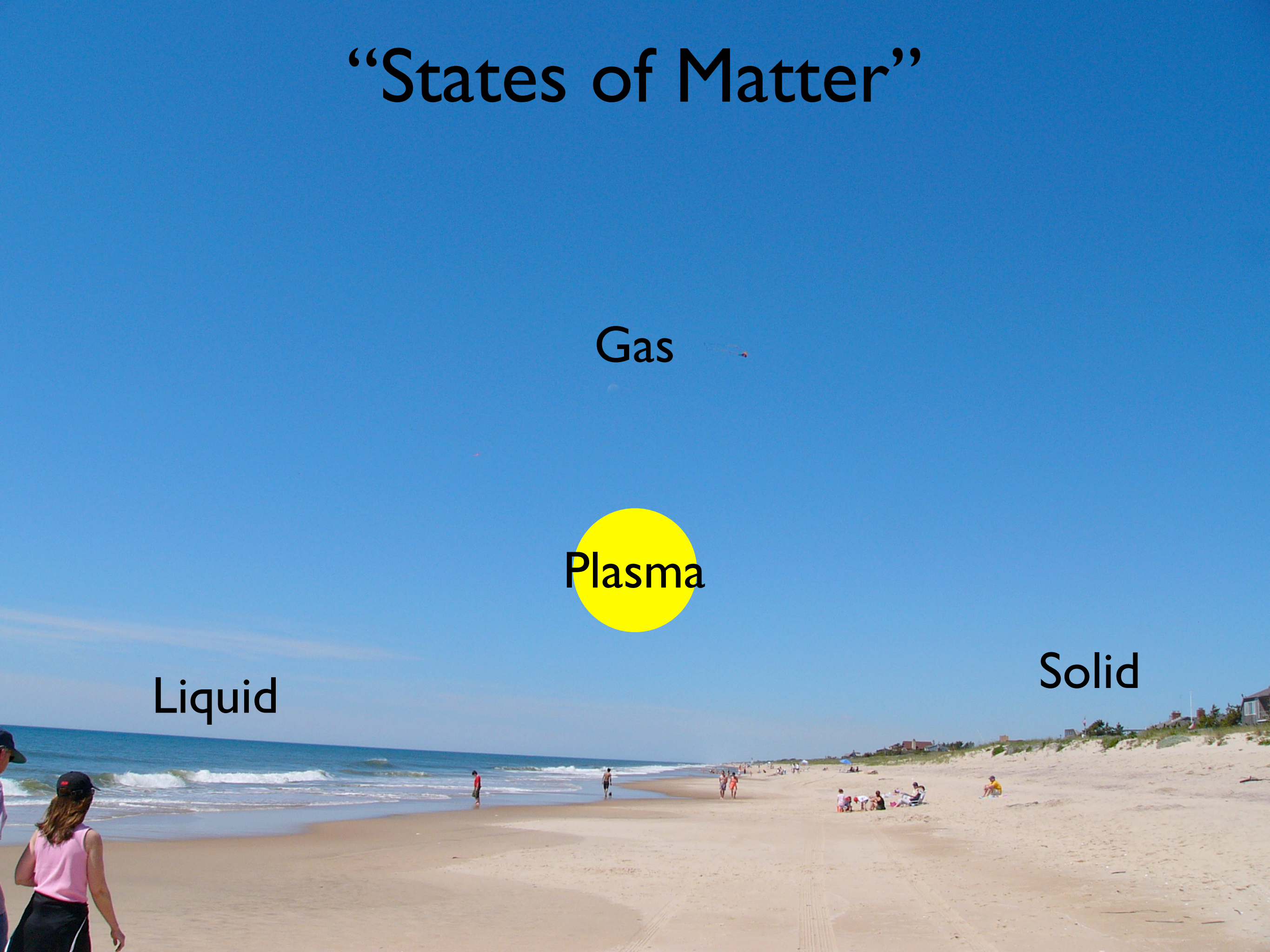
“States of Matter”

Gas

Plasma

Liquid

Solid



Underlying Dynamics

The universe, beyond the visible sky

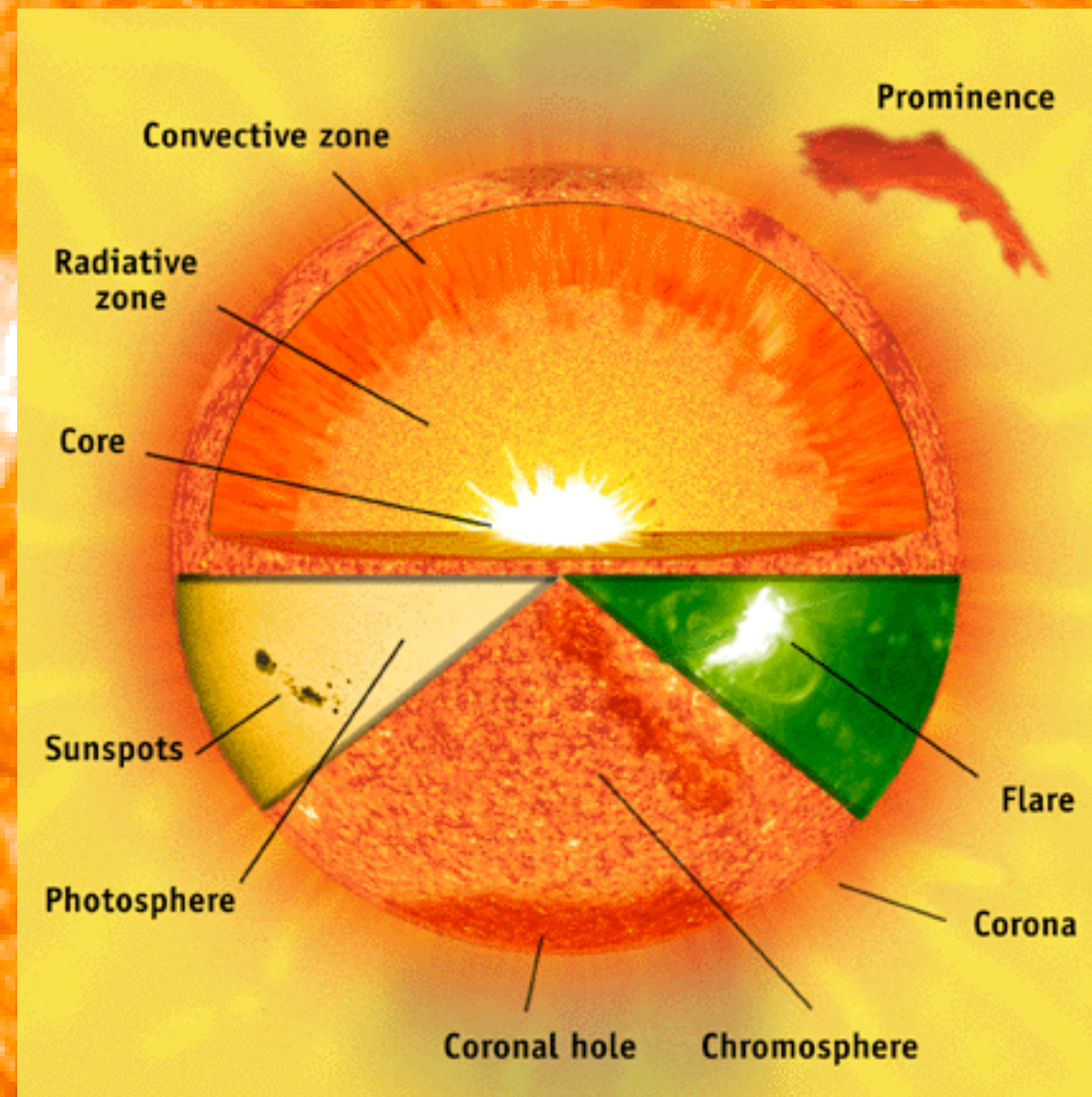
Light from the sun (scattering off of the atmosphere,
making the sky blue!)

Waves in water

Geological dynamics



“Temperature” of the Sun



Core of the sun is 13–25 million °K
Surface of the sun is 7000°K

Physics: It's all around you,
but is often hidden from view



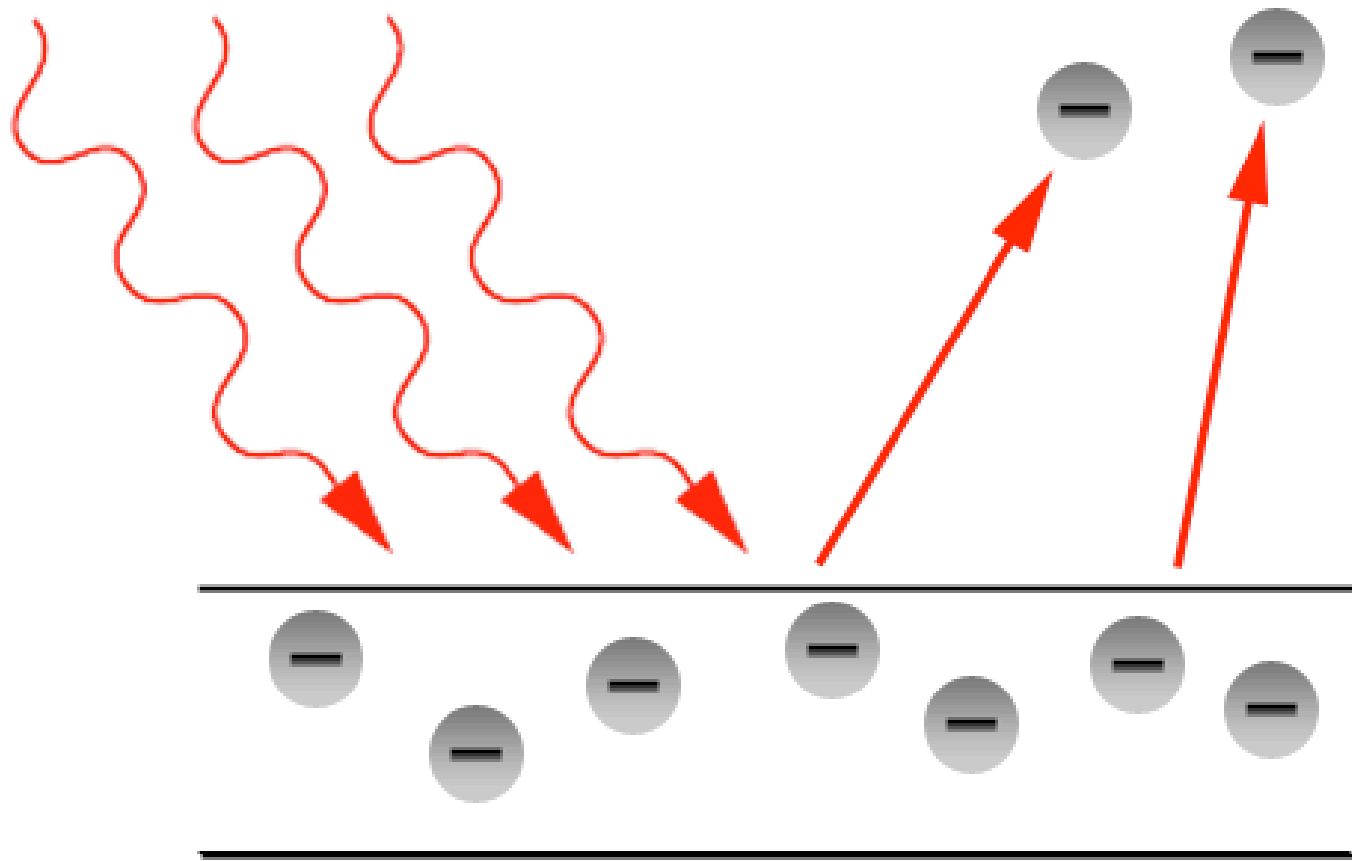
What difference can a year make?



In a single year,
1905,
Einstein published
four papers, three of
which could have
won a Nobel Prize
(and one did!)

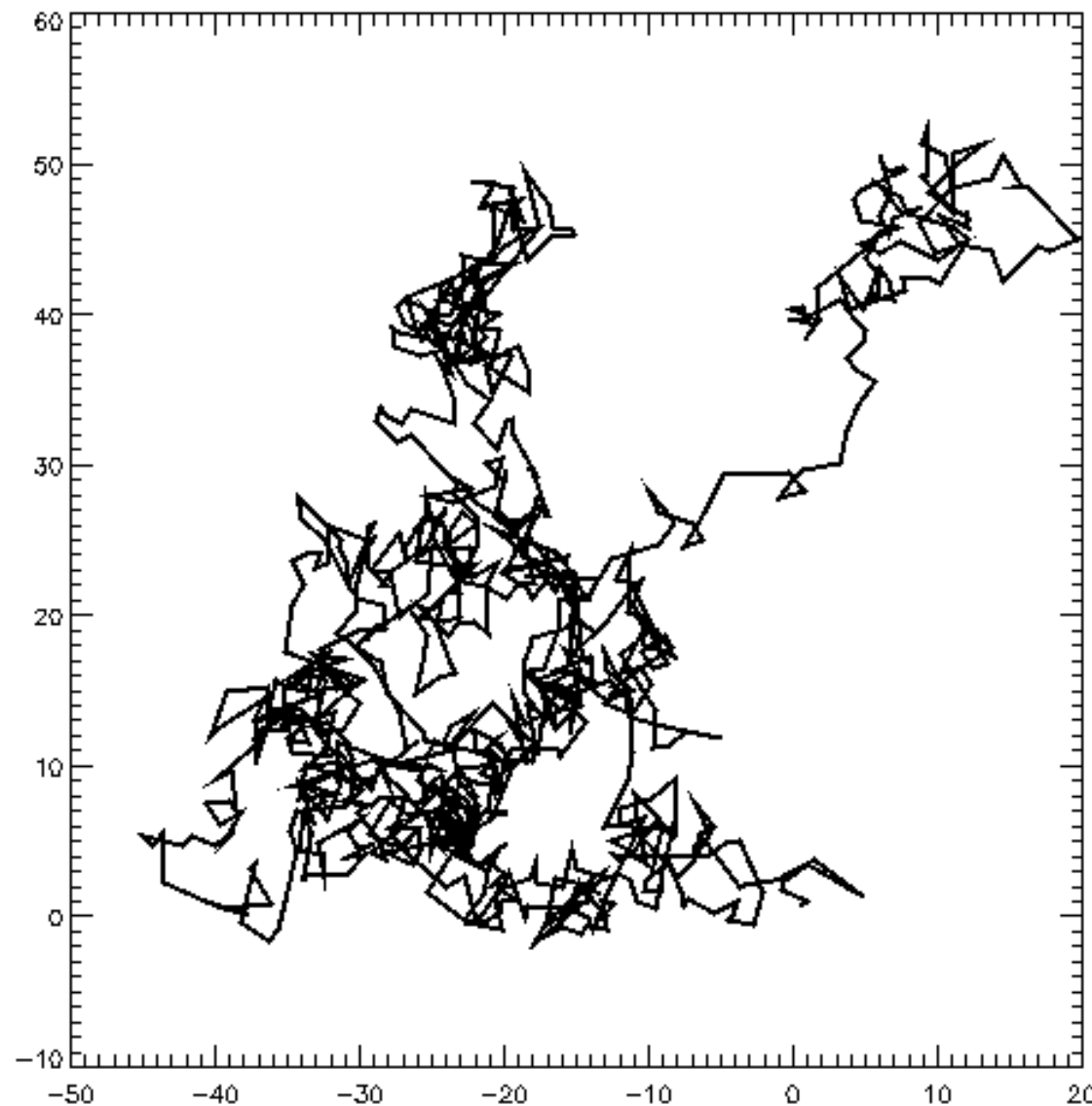


Rate of electron emission from a metal depends on a minimum frequency (energy) and not just on the intensity of the light



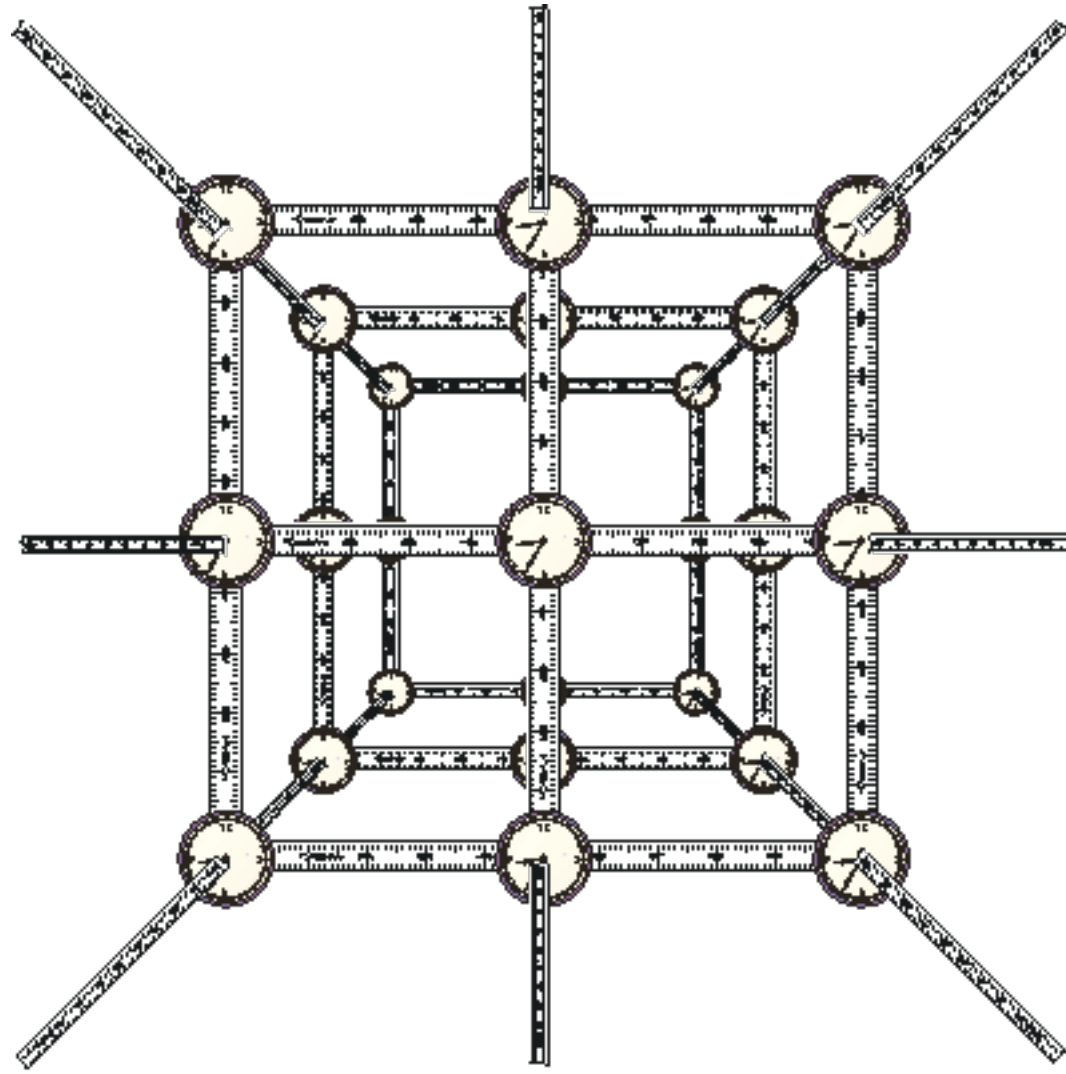
March 1905 - Einstein publishes paper on the “photoelectric effect”, determining that light has irreducible “particle” aspects.

Important precursor to Quantum Theory



May 1905 - Einstein publishes paper on the “Brownian Motion”, explaining jagged paths of particles suspended in solution.

Helped us understand atomic nature of matter



June 1905 - Einstein publishes paper on the “Electrodynamics of Moving Bodies”, where he gives the formulae of the Theory of Special Relativity

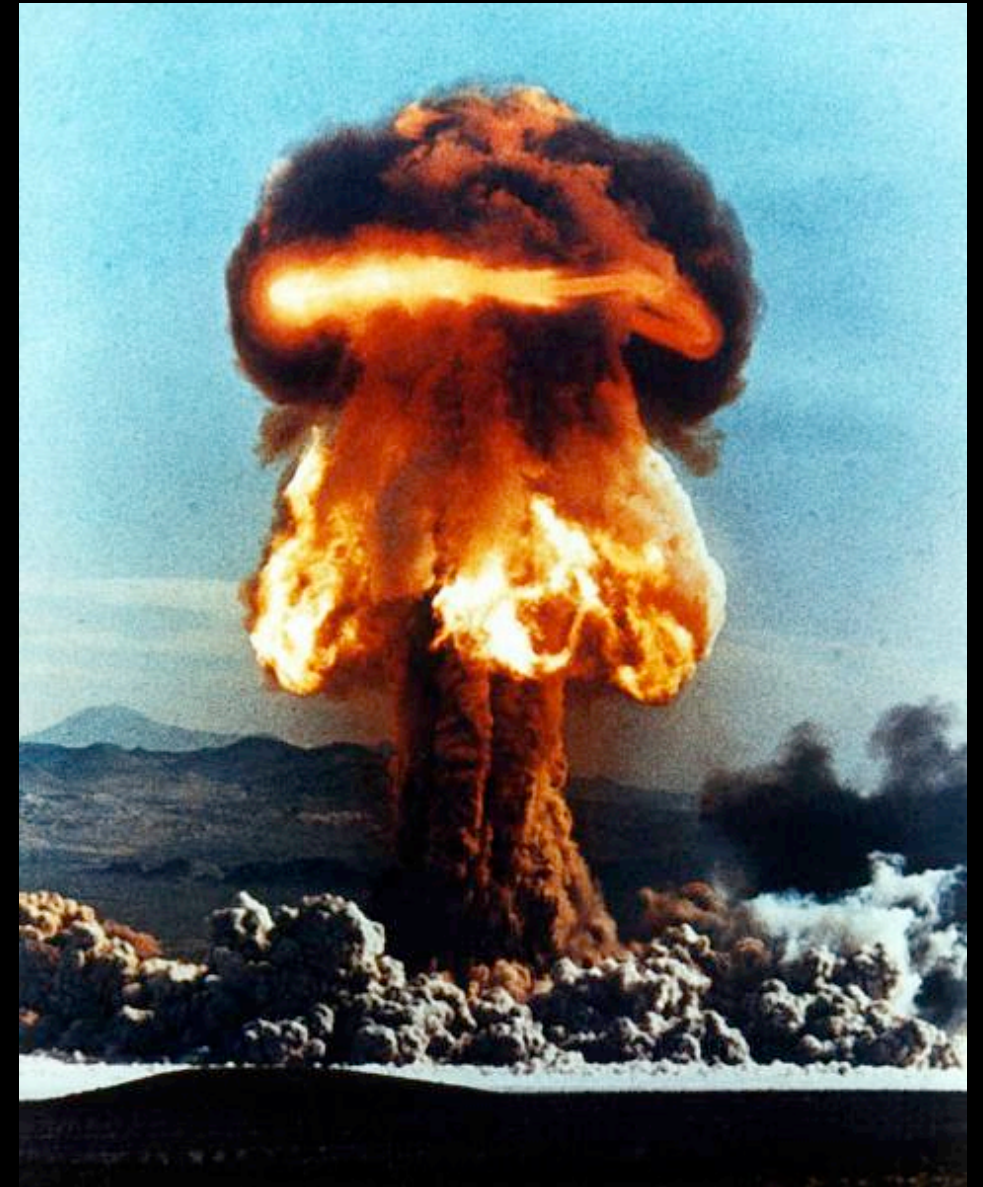
Completely upended classical view of space-time

$$E = mc^2$$



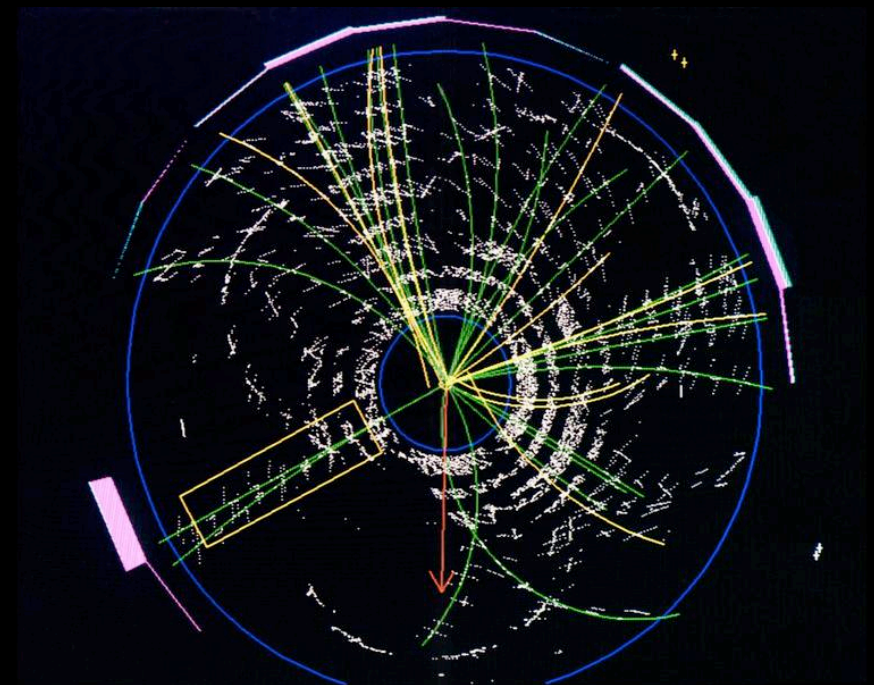
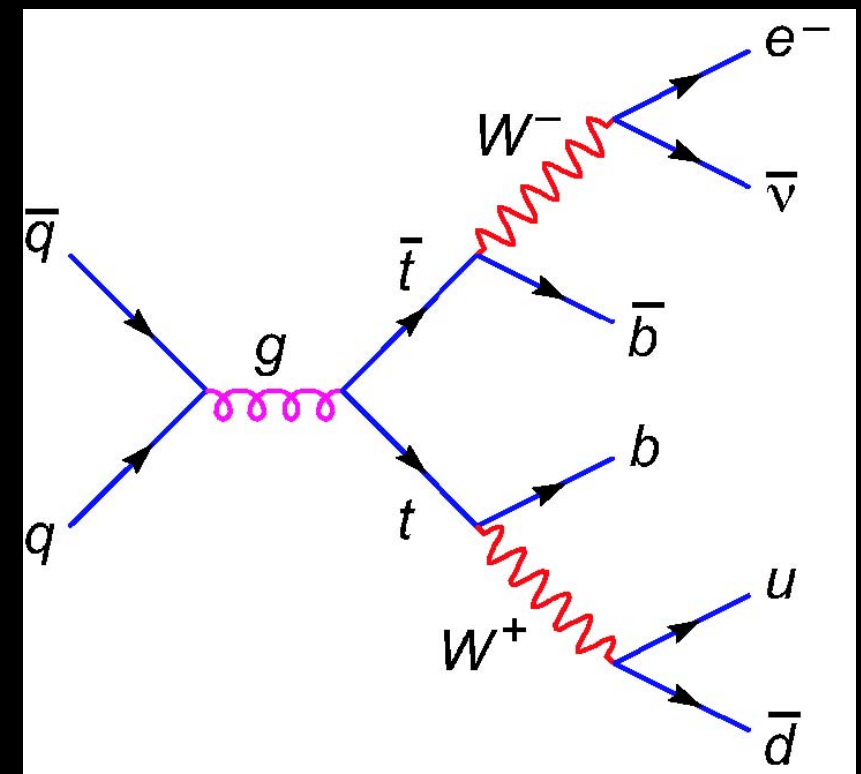
September 1905 - Einstein publishes paper, “Does the Inertia of a Body Depend on Its Energy Content?”, where he gives his most famous formula

$$E = mc^2$$



Of course, the conversion of mass to energy is the basis of the physics used to release energy from the nucleus: for benign and malign purposes...

$$E = mc^2$$



It is also the foundation of modern particle physics,
colliding elementary particles at such high
energies that new particles are created

$$E = mc^2$$
$$t = -19.800$$

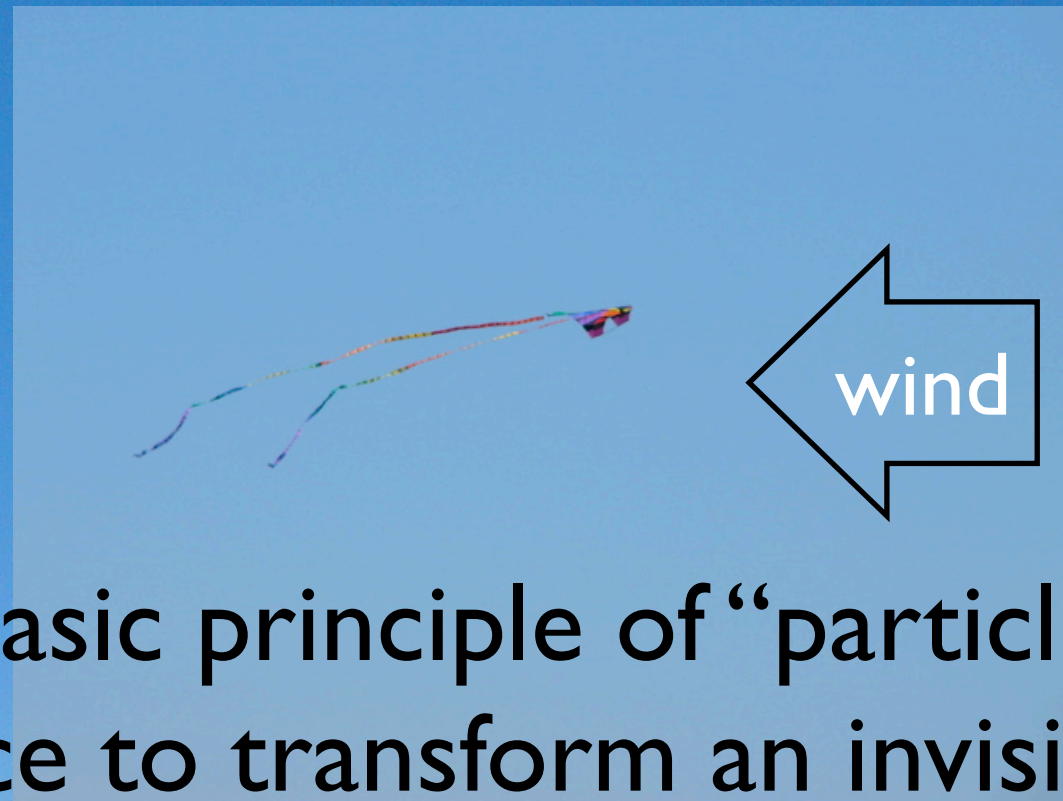
It is also the foundation of the physics we do at RHIC,
colliding ions at such high energies that 400 particles
turn into nearly 10,000 of them!

RHIC @ BNL



Question: The air is transparent. How do we “see” it?

Answer: We can see it push things around, like kites...

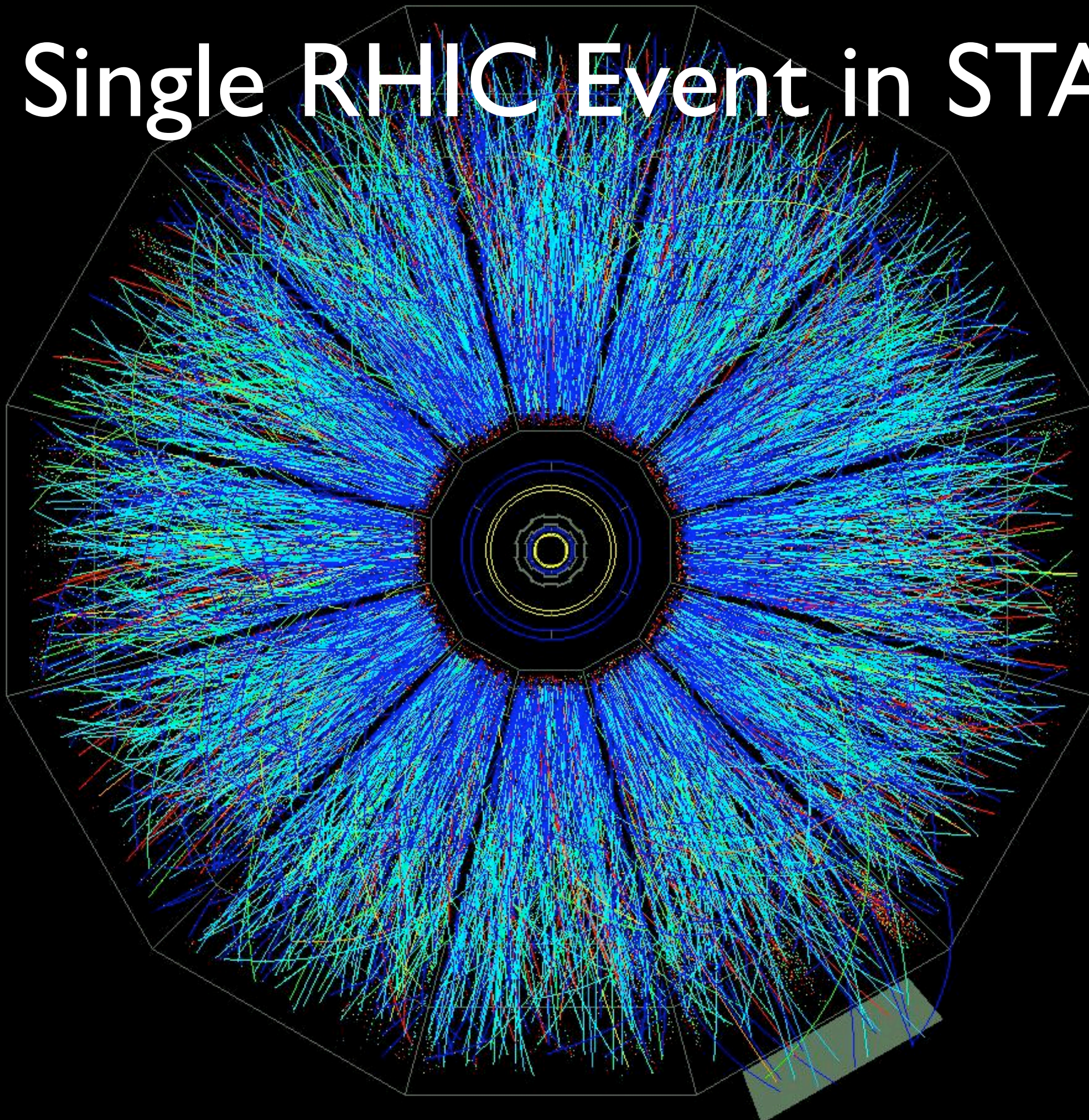


This is the basic principle of “particle detection”,
use a device to transform an invisible particle
into something we can see (& record!)

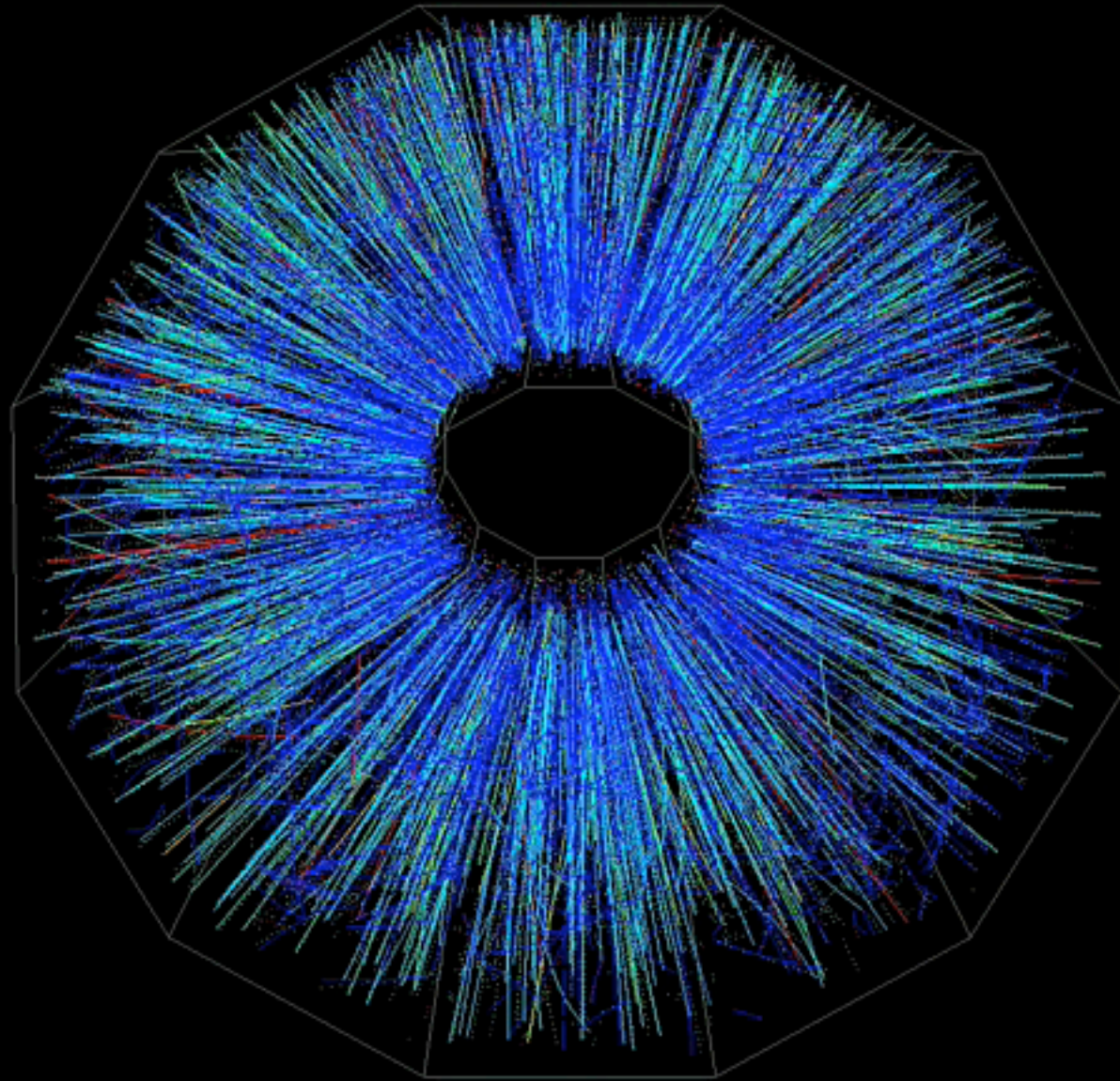
The STAR Detector



A Single RHIC Event in STAR



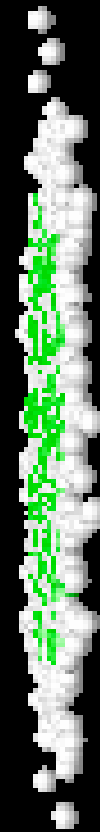
A Single RHIC Event



STAR: A giant 3D camera...



How much
energy
in each
collision?



$$1.6 \times 10^{-19} \frac{J}{eV} \times 197 \times 200 GeV \sim 6 \mu J$$



Consider
two mosquitos
colliding...



$$2 \times \frac{1}{2} m v^2 = (1g) \times (10cm/s)^2 = 10 \mu J$$

“Temperature” of RHIC

$$T_{ch} = 177 \text{ MeV}$$
$$\mu_B = 29 \text{ MeV}$$

π

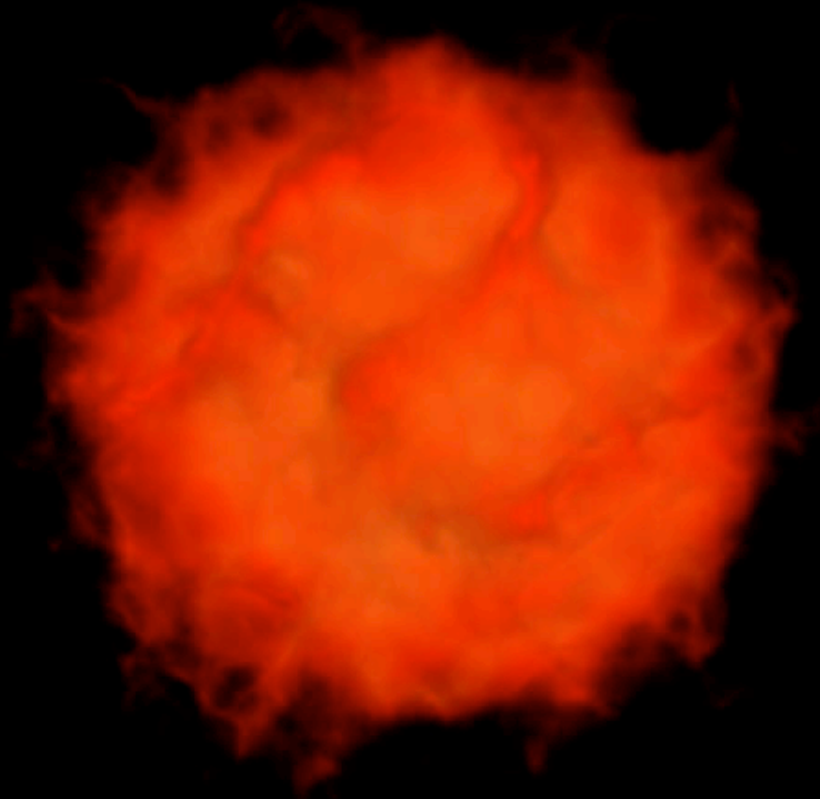


This is $\sim 2 \times 10^{12}$ degrees K

This is, in some sense, the
“surface temperature”
of a RHIC collision, when
it “freezes” into hadrons

The “core” must have
been much hotter!

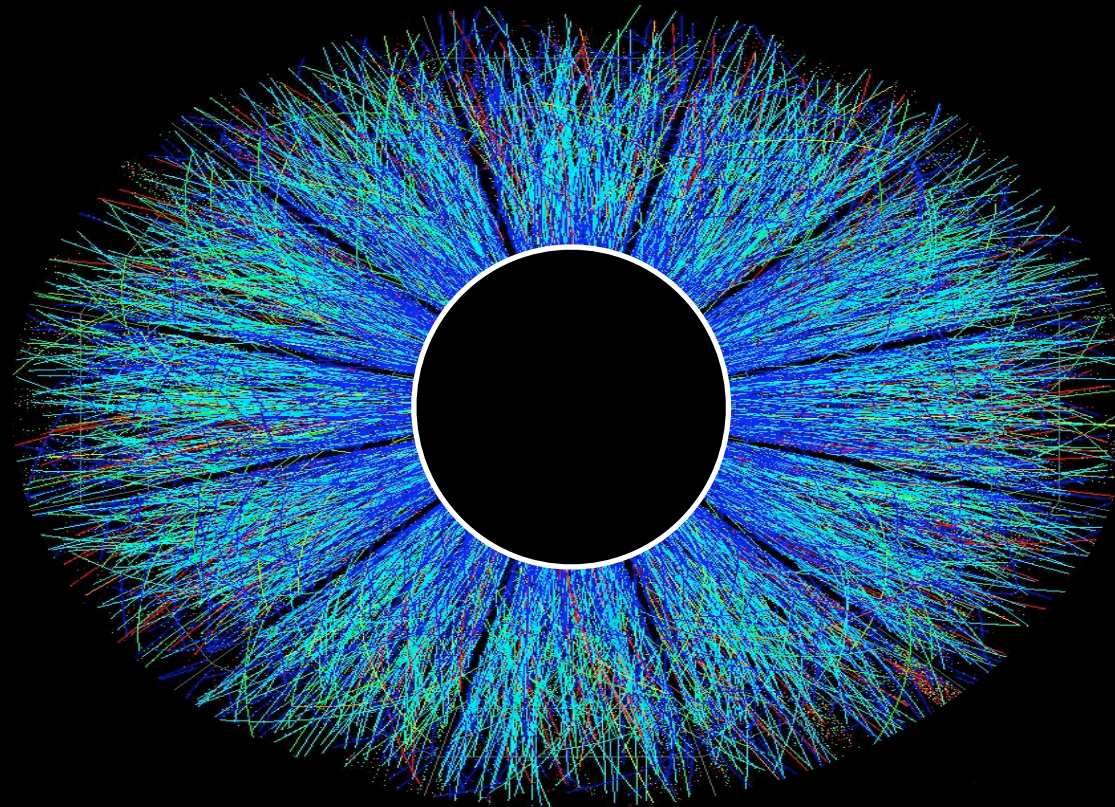
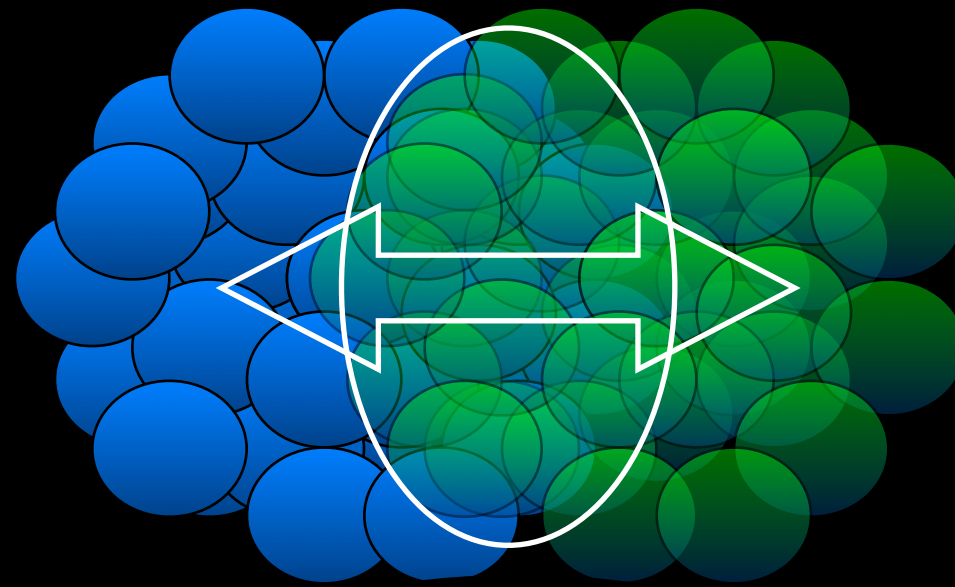
Is RHIC a gas or a liquid?



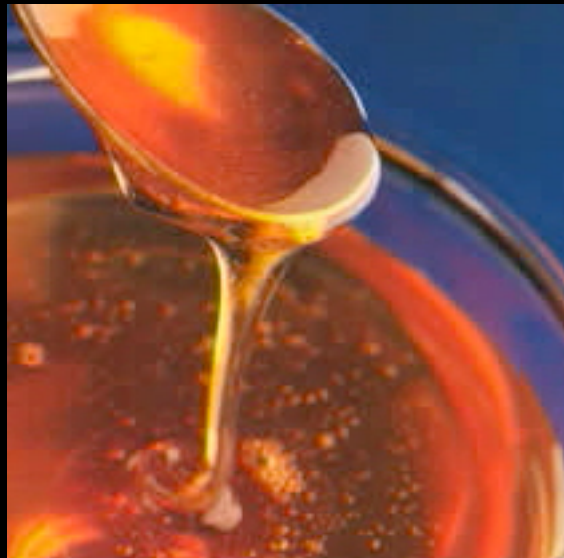
Is the system just
a “fireball”, just radiating
into free space?



Or is the system
more “explosive”, with
explosive dynamics preceding
the freezeout?



Even at these high energies,
RHIC “flows” like a fluid



Honey



Water



Superfluid He³

A perfect fluid is one where there is no resistance to the liquid flowing

We say that a perfect fluid then has zero “viscosity”, the feature of “sticky” liquids like honey

Black Holes at RHIC?



not exactly...

Viscosity in Strongly Interacting Quantum Field Theories from Black Hole Physics

P. K. Kovtun,¹ D. T. Son,² and A. O. Starinets³

¹*Kavli Institute for Theoretical Physics, University of California, Santa Barbara, California 93106, USA*

²*Institute for Nuclear Theory, University of Washington, Seattle, Washington 98195-1550, USA*

³*Perimeter Institute for Theoretical Physics, Waterloo, Ontario N2L 2Y5, Canada*

(Received 20 December 2004; published 22 March 2005)

The ratio of shear viscosity to volume density of entropy can be used to characterize how close a given fluid is to being perfect. Using string theory methods, we show that this ratio is equal to a universal value of $\hbar/4\pi k_B$ for a large class of strongly interacting quantum field theories whose dual description involves black holes in anti-de Sitter space. We provide evidence that this value may serve as a lower bound for a wide class of systems, thus suggesting that black hole horizons are dual to the most ideal fluids.

DOI: 10.1103/PhysRevLett.94.111601

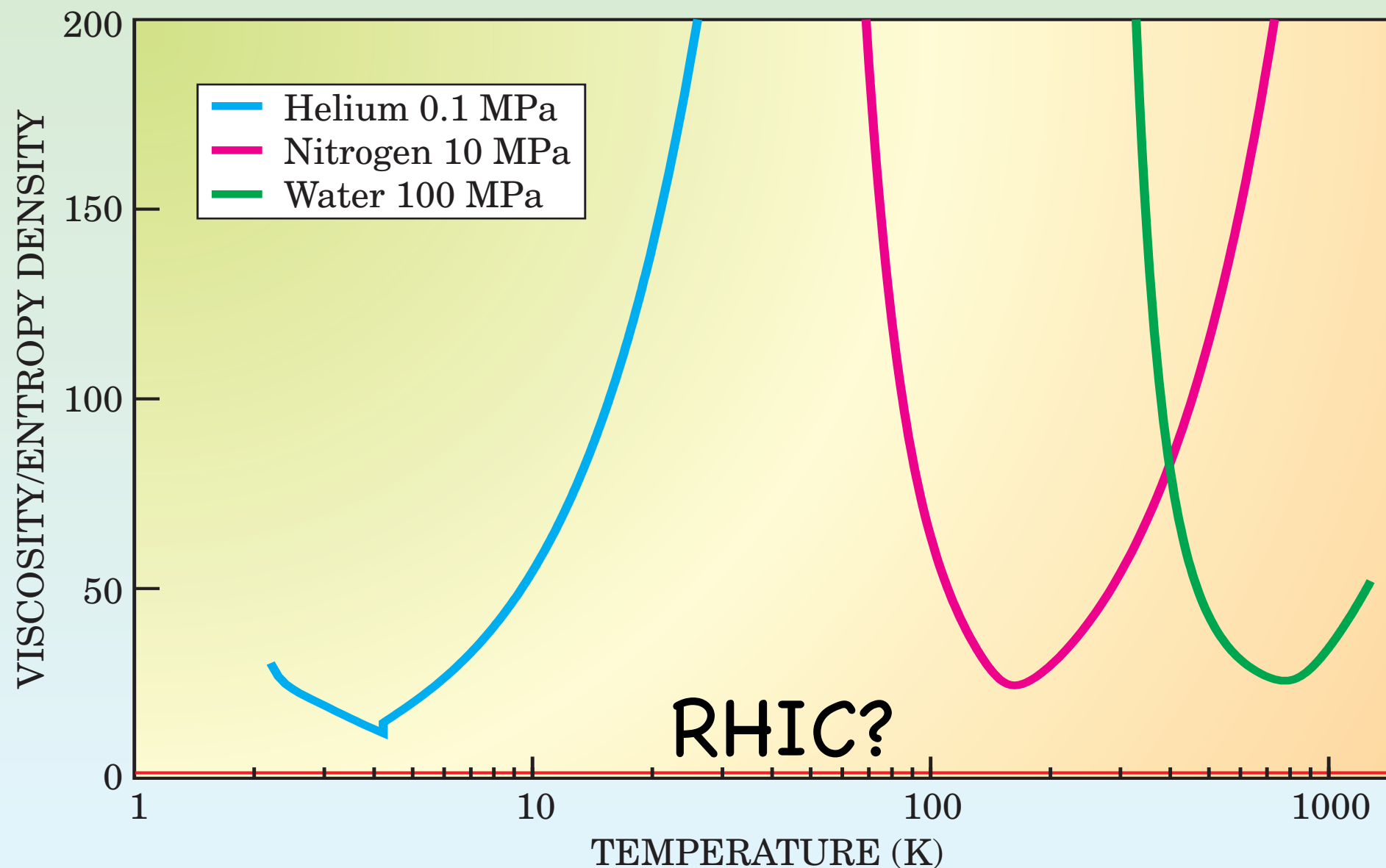
PACS numbers: 11.10.Wx, 04.70.Dy, 11.25.Tq, 47.75.+f

Details aside, this paper makes a calculation about
RHIC physics using a 10 dimensional black hole
and gets a meaningful result about its viscosity...

Lower Viscosity Bound

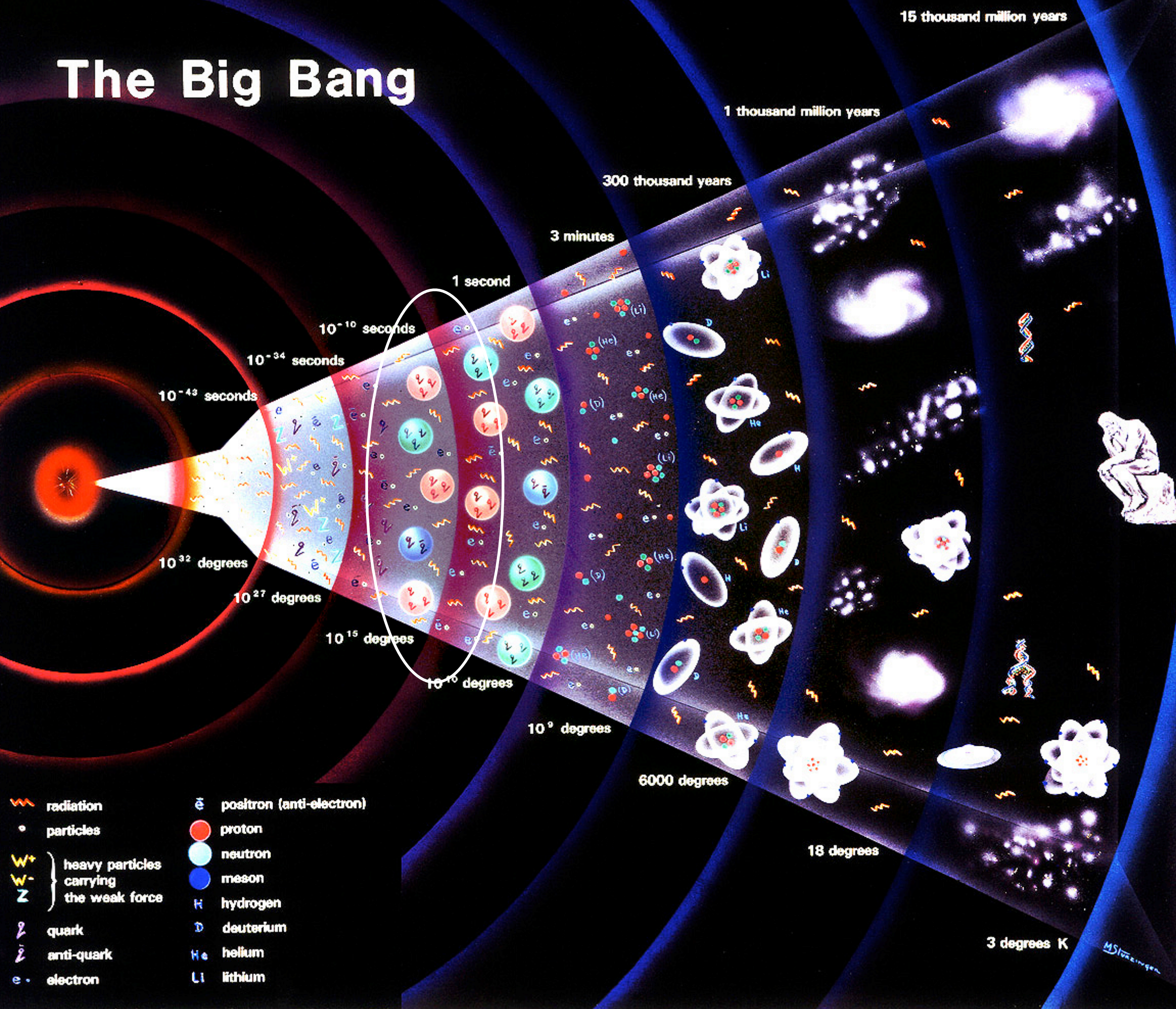
Physics Today, May 2005

P. K. Kovtun, D. T. Son, A. O. Starinets, *Phys. Rev. Lett.* **94**, 111601 (2005).



A perfect liquid is impossible - but is RHIC the most perfect?

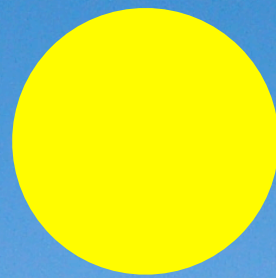
The Big Bang



So what have we found at RHIC?

We thought it would be a gas of quarks & gluons,
or more like a plasma

But it turns out to
have fluid-like
properties





What a difference a year can make!

What difference can a year make?



We don't get many chances to think
about what we do

Nor do we get many chances to try and describe
what we do for a wider audience

InterAction collaboration, a consortium of the
public affairs departments of physics labs worldwide,
decided that they could reveal the creative energy
of physicists from all over the world by using
the power and immediacy of the internet

“web log” → “blog”

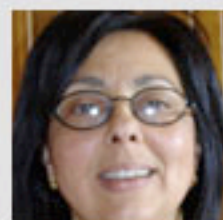
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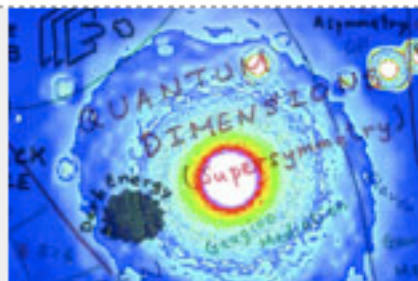


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Rosa Alba
INFN
Italy
Lang: Italian

Anche Rosa da piccola voleva fare l'archeologa, ma i corsi di fisica al liceo l'hanno motivata per cambiare indirizzo e scegliere fisica all'università. Oggi Rosa svolge la sua attività sperimentale presso i LNS e l'INFN.

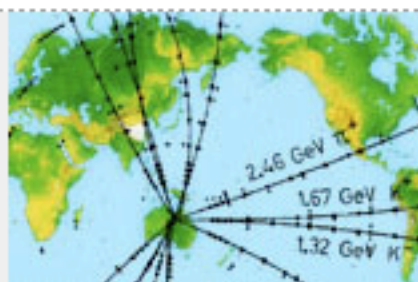


New

What's your secret?
Gordon Watts' students want to know: How does he get that gorgeous, stick-straight hair? (posted 6/2)

Physics Theory
Or is that a lecture on physics theory and then...karaoke! Claire Gray's physics summer school experience continues to rock. (posted 6/3)

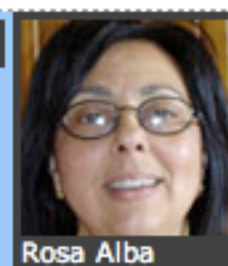
WANTED: A Ph.D.
Caollonn O'Connell shares the good, the bad, and the ugly of defending a Ph.D. thesis. (posted 6/3)



June 2, 2005

This is great. I've always dreamed of releasing a CD...but I never thought I'd have to share the credit with 1000 other scientists! Read more...

Peter Steinberg



June 3, 2005

In fondo, penso che in dei giovani di 16-20 anni l'entusiasmo debba essere la molla prevalente nel gettare le basi per il proprio futuro. Legga più...

Rosa Alba

The Physicists



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Brookhaven, USA,
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[Tommaso Dorigo](#)
Fermilab, USA
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[VIDEO](#)



[Sophie Trincz-Duvoid](#)
IN2P3, France
Lang: French
[BLOG](#)



[Ursula Bässler](#)
IN2P3,
France
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[VIDEO](#)



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KEK,
Japan
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[Jose Ucariz](#)
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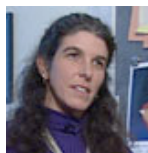
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[Makoto Fujiwara](#)
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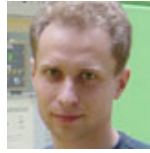
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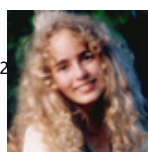
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Pierre Auger
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[Claire Gray](#)
Wits University/
Jefferson Lab
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[Sarah Phillips](#)
Jefferson Lab
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[Anuj Purwar](#)
Los Alamos
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[Rob Gardner](#)
Univ. of Chicago
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33 Physicists, 16 Nations

One World Year of Physics!

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PETER STEINBERG

Brookhaven



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[Feynman @ BNL \[Updated!\]](#)

[Stamping Out Ignorance...](#)

June 02, 2005

QGP on CD

I have mentioned the RHIC "Whitepapers" in previous posts, mainly since their public availability was associated with a major press release just this past April. What I hadn't appreciated was that we'd get a nice CD out of the bargain, almost free of charge, with renderings of our iconic event displays.



This is great. I've always dreamed of releasing a CD...but I never thought I'd have to share the credit with 1000 other scientists!

June 02, 2005 at 01:37 PM | [Permalink](#) | [Comments \(0\)](#)

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SOPHIE TRINCAZ-DUVOID

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Après la these
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Congratulations Chris and Fred!
Mariages
stagiaires et thesards
decalage horaire
déjà le retour
a fnal
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SHOHEI NISHIDA

KEK

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最近の投稿

J-PARC

Apr 15th.

Sakura

スマトラ地震

Event display at Belle

サンディエゴ

I'm back

KEKB is now O.K.

new hybrid particle

Super Belle

アーカイブ

5月 2005

4月 2005

5月 17, 2005

J-PARC

日記を書くのが随分、久しぶりになってしまいました。

今日は、茨城県東海村にある原研の J-PARC (大強度陽子加速器) の建設現場の見学ツアーに参加してきました。J-PARC は大強度の陽子ビーム (例えば 50GeV 750kW) を使って、ニュートリノ実験をはじめとする素粒子実験や、原子核実験、中性子を用いた物質科学などを行うプロジェクトです。2007 年ごろに運転開始だそうです。



J-PARC の全体図はこのような感じになのですが、今回はリニアック、3GeV シンクロトロン、50GeVシンクロトロンなどを見学してきました。



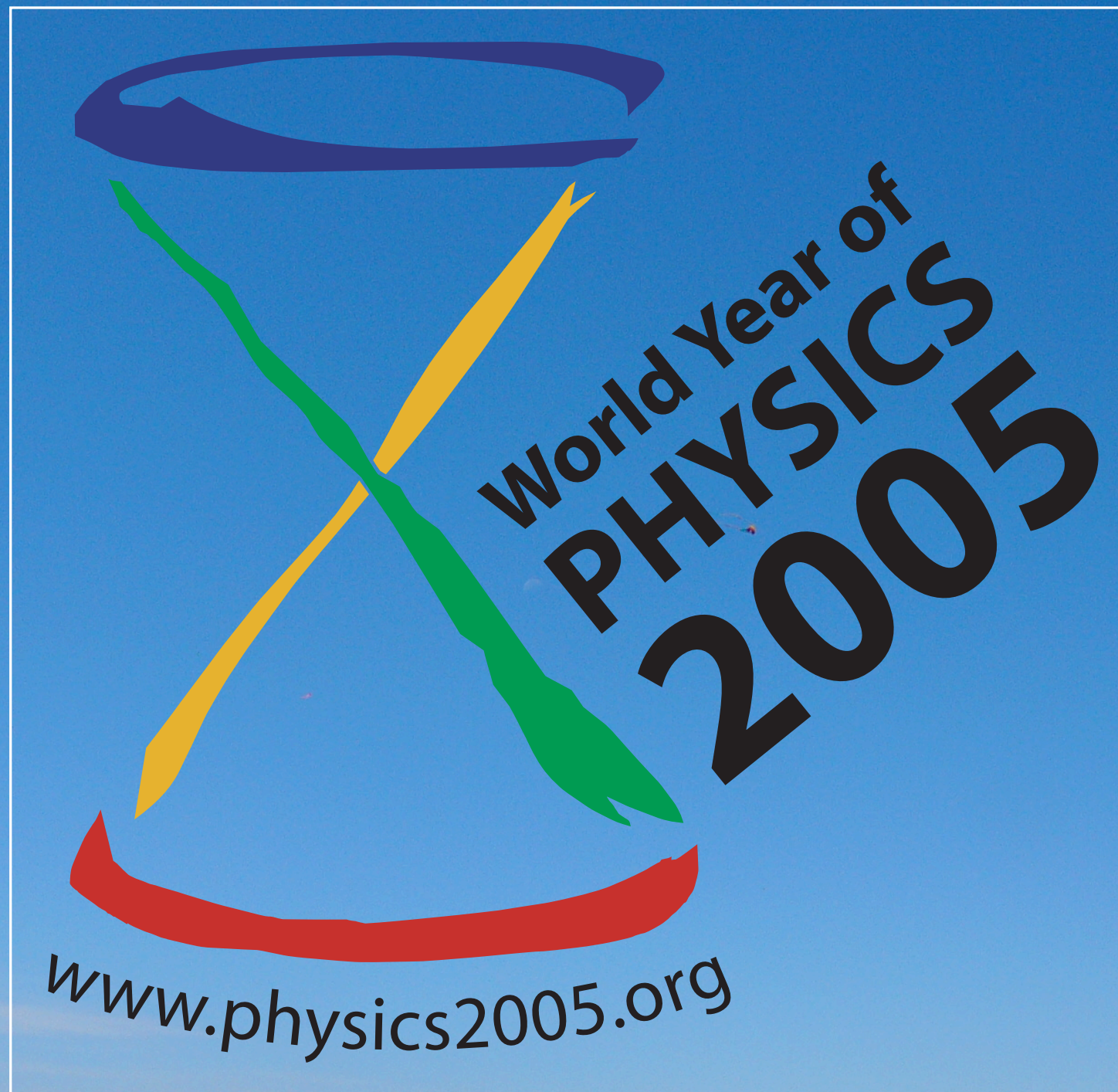
陽子リニアックのトンネルは完成していましたが (左の写真)、まだ装置類は何もないので広々としてました。このトンネルは壁がすごく厚いです。右の写真は、3 GeV シンクロトロンの一部で、50 GeV シンクロトロンや物質生命科学実験施設への分岐点です。この辺りは工事もしましたが、もう少して完成というところでした。



しかし、ここから先、50 GeV シンクロトロンとかニュートリノ実験施設は、まだ完成していません。

Who knows what one of us will come up with
on a sunny day on the beach in 2005?







BNL has been taking an active role in the World Year of Physics 2005, with lectures and events all year...

